British Journal of Anæsthesia

VOL. XI. No. 3. APRIL, 1934

EDITORIAL.

All contributions to be sent to the Editor, 29 St. Andrew's Mansions, Dorset Street, W.1.

FATALITIES associated with anæsthesia are not diminishing with the rapidity that every anæsthetist must desire. It is, indeed, maintained in some quarters that these fatalities are not only not diminishing but are increasing. In actual numbers this may be true, but it is not true proportionately. The number of operations performed yearly has increased in greater proportion than the number of deaths attributable to anæsthetics. Nevertheless it must obviously be a primary aim of all anæsthetists still further to reduce the yearly mortality for which their art can be held responsible. There is only one way to do this. It is by an ever-increasing improvement in the extent and nature of instruction in anæsthetics, and by an ever-increasing practice of deputing the position of anæsthetist to those only who are by training and experience really competent to assume the responsibility with safety to the patient and comfort to the surgeon. We are a long way yet from the time at which the necessity for this will be always recognized and acted on, not only by surgeons but by the general public. There are still far too many institutions to

which the "anæsthetist" is one in name only, and far too many surgeons who are willing, for reasons of finance or convenience, to entrust their patients to "anæsthetists" not fitted for the task.

POST-OPERATIVE PULMONARY COMPLICATIONS.

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GENERAL CONSIDERATIONS.

IT has long been recognized that there is always a certain incidence of complications following surgical interference with the human body. In these complications pulmonary conditions figure more largely than any others, as can be shown by the analysis of any large series of surgical cases.

The most common types encountered are bronchitis, broncho-pneumonia, and conditions involving some degree of collapse of the lung, and it is here proposed to consider only these.

In the past these pulmonary complications have been attributed very largely to the use of inhalation anæsthetics. It would be reasonable, therefore, to expect a reduction of the morbidity with the more general use of regional anæsthesia. This, however, does not seem to be so, as the following record of cases shows, and this investigation is an attempt to determine the aetiology and correct treatment of these conditions.

Pulmonary embolus may be regarded as separate from post-operative conditions, since it may occur apart from any operative interference. In any case, it is difficult to show its connection with anæsthesia, and an attempt would carry the investigation far beyond the scope of this thesis.

REFERENCES.

Lichtheim,[1] in 1879, first proved that collapse of alveoli was due to the absorption of alveolar air into the blood-stream.

This work was followed by a paper by Pasteur,[2] in 1908, in which he quoted cases where collapse and broncho-pneu-

monia were found at post-mortem examination following diphtheritic paralysis of the diaphragm. He applied these findings to similar post-operative conditions, and noted that a very large majority of cases followed abdominal operations. He attributed this to impaired movement of the diaphragm, and thought it unlikely that the irritation of the anæsthetic played any great part in causing the complications.

Elliott and Dingley[3] describe eleven cases of collapse, and consider that the condition is due to blocking of the bronchioles by muco-purulent material. They quote the experiment done by Lichtheim when he put a laminaria tent into the bronchii of rabbits with resulting collapse.

They recommend the avoidance of tight bandages and full inspiratory movements (particularly of the abdominal type) for all patients after operation.

Pasteur in a later paper[4] follows up his previous observations on the movements of the lungs, and adopts Keith's views that the lungs are expanded by two forces, namely that the upper parts of the lungs are expanded by the upper six ribs, and the lower parts by the diaphragm using the lower ribs as an anchorage.

He considers that two factors are pre-eminent in causing collapse:

(1) Access of infective material to the lung.

(2) Serious lessening or temporary arrest of the respiratory power.

He gives the physical signs of the condition as: (1) Dullness over the affected base with silence or tubular breathing. (2) Diminished movement of the affected side with compensatory movement of the unaffected side. (3) Displacement of the heart to the affected side.

He recognizes two types, namely "acute" and "latent." He states that collapse occurs almost always at the right base, and that he has never seen collapse of both bases.

His percentage of recorded complications is somewhat similar to that in this series of cases for the upper abdomen, although his percentage for the lower abdomen is rather smaller. Also his differential tables are hardly comparable with those which follow, as entirely different methods of anæsthesia were employed.

Briscoe,[5] in experiments on rabbits, could produce no collapse by irritating the diaphragm by chemical and mechanical devices, or by introducing irritant substances into the pericardium, and concludes from this evidence that Pasteur's theory that collapse was dependent upon paralysis of the diaphragm is untenable, and that no evidence of reflex inhibition of one side of the diaphragm had been obtained. Upon further consideration of his (Pasteur's) work he noted that: (1) All the patients were seriously ill, and (2) that their illnesses necessitated a supine position. He investigated 30 cases of uncomplicated abdominal operations, and found that 11 had deflation of the lower lobes, and that those with deflation showed no tone or action of any abdominal muscles. He accordingly investigated the effects of the supine position on normal people. In the erect position he divided his subjects into three classes: (*a*) Those with no contraction at all of the lateral abdominal muscles; (*b*) those with a contraction increasing progressively during expiration; (*c*) those with a tone which does not vary during inspiration and expiration. He considers that 95 per cent of adults fall into class (*b*).

In the supine position this classification becomes modified. Those people in class (*a*) remain unchanged; those in division (*b*) either pass into class (*a*) or remain in division (*b*) (with diminished force); those in division (*c*) pass into (*b*), or even into (*a*). These changes take place almost immediately upon the assumption of the supine posture.

With regard to the auxiliary muscles of respiration he found that in class (*a*) the scaleni behave in a varied manner, and the triangularis sterni is expiratory, but in class (*c*) the scaleni, triangularis sterni and transversalis abdominis are inspiratory.

He produced X-ray tracings to show that the diaphragm, apex beat, and liver rise more in the supine position in the (*a*) than in the (*c*) class, and came to the conclusion that lack of contraction of the abdominal muscles [class (*a*)] caused a predisposition to collapse. Particularly is this so when there is lack of action of the costal portion of the diaphragm whilst the crus acts normally (right contracting more than left).

He considers that attacks with pain are always due to a

small patch of pleurisy, and those without pain are due to secretion accumulated on top of an already deflated lung (the patient is therefore unable to remove this secretion by coughing).

As prophylaxis he recommends the avoidance of prolonged repose in the supine position.

Scott and Cutler[6] believe that complications are initiated by a nervous reflex, largely vaso-motor, resulting in a narrowing of the lumen in the peripheral bronchioles by venous engorgement, swelling of the mucous membrane, and the elaboration of a tenacious secretion. They also think that quantitative changes in ventilation may be significant in cases where unilateral complications are found. They recommend:

(1) That all patients operated upon under general anæsthetics be given hyper-ventilation, by means of carbon dioxide in oxygen, at the end of the operation. (2) That the patient should be kept in a semi-Fowler position if possible, and should not lie on one side. (3) That the patient should be given periods of deep breathing for the first 24 hours after operation. (4) That post-operative dressings should not hinder respiration.

Sante[7] supposes a condition of collapse to be due to the inhibition of the cough reflex by some toxic or reflex stimulus in association with impairment of the respiratory muscles, which permits secretions to accumulate and block the bronchus, so that atelectasis results. His treatment consists of rolling the patient back and forth on the uninvolved side, or, if this fails, the bronchosopic removal of the mucus.

Lee, Tucker and Clerf[8] suggest that phenomena of pulmonary collapse of varying degrees are the real aetiological factors in post-operative pulmonary conditions. They quote these degrees as: (1) Massive atelectasis involving more than one lobe of the lung; (2) lobar atelectasis; (3) lobular atelectasis. They suggest that there are two factors in the cause: (1) Viscid bronchial secretions; (2) inhibition of coughing. They cite a case where 9 c.c. of thick secretion were removed from the bronchus, with recovery of the patient. This secretion, when introduced into a dog under operative conditions caused typical atelectasis.

This paper was followed by one from Lee, Ravdin, Tucker

and Prendergrass[9] in which they describe how they introduced a solution of 100 per cent gum acacia (which corresponded in viscosity to the bronchial secretion extracted from the above-mentioned patient) into the bronchi of dogs. After the introduction of this solution the dogs showed typical atelectasis.

Their work has been continued in England by Band and Hall,[10] who did a further series of experiments on dogs.

They found that laparotomy produced no effect upon the lungs.

The introduction into the right bronchus of solutions of gum acacia of strengths up to 50 per cent produced a few scattered areas of collapse, but a solid foreign body inserted into the bronchus was found to be coughed out again. A solution of 40 per cent acacia was next introduced, and strapping was applied to the ribs, and this combination produced considerable collapse. Similar collapse was produced by a 75 per cent solution and strapping of the ribs. Avulsion of the phrenic nerve was next performed, but no collapse followed. This operation, however, when combined with the introduction of 75 per cent acacia solution did produce collapse.

They consider that three factors are responsible, namely: (1) An intra-bronchial content of definite viscosity; (2) the abolition of the cough reflex; (3) limitation of respiratory movement.

A different line of thought has been followed by Foss and Kupp,[11] who advocate the theory that pulmonary complications are of embolic origin. They state that each variety of complication is seen after a different period, namely: Lobar pneumonia about the fifth day after operation; bronchopneumonia about the seventh day; massive collapse about the second day, and bronchitis during the first week. Their reasons for assuming an embolic origin are: (1) That the onset is usually after the sixth day, with sudden pain, few rales, impaired breath-sounds, and rapid recovery; (2) that more than one attack is seen; (3) that the conditions are frequently associated with phlebitis; (4) the occurrence of complications following local anæsthesia.

They also report 400 abdominal operations under spinal

anæsethesia in which the incidence of pulmonary complications is the same as with general anæsthesia (i.e. 1.7 per cent). They consider that the irritation of an anæesthetic probably plays some part in the incidence, but that the fact that complications occur with spinal and regional anæsthesia suggests other factors. They make three proposals for treatment: (1) Ventilation with carbon dioxide and oxygen (Scott and Cutler); (2) change in the position of the patient every six hours; (3) the curtailment of post-operative sedatives, and the bronchoscopic removal of mucus.

Ravdin and Kern[12] classify complications into two groups, one of which consists of cases following upon previous infection of the respiratory system. This group of complications consists of the lesions of lobar pneumonia, broncho-pneumonia, and bronchitis, and shows a seasonal variation, being most common in the winter. The second group they compose of embolism and atelectasis, and state that this group (which consists of 13 cases, as against 56 in the first group) shows no seasonal variation. They also state that prolonged anæsthesia causes a higher incidence of complications.

Jones and McClure[13] recommend the use of a transverse incision, and claim a reduction of 50 per cent in chest complications following its use.

Definition of Pulmonary Complications.

A pulmonary complication was diagnosed whenever a cough with sputum was noted after operation.

Classification of complications must, of necessity, be somewhat arbitrary, as the dividing lines between bronchitis and broncho-pneumonia, and between broncho-pneumonia and the milder degrees of collapse, are not easily drawn. For this reason the cases in this series have been divided into two classes only. The first consists of bronchitis and broncho-pneumonia, and the second of cases in which there was clinical evidence of some degree of collapse of lung.

Anæsthesia.

There were four methods of anæsthesia used for this series of cases. The greatest number of cases was performed under "General" anæsthesia. This group includes chloroform,

ether, mixtures of these two, and nitrous oxide and oxygen with ether added to it.

"Regional" anæsthesia was used for another group of cases. This consists of infiltrating the nerves supplying the area to be operated upon with an anæsthetic solution. In the gastric operations the splanchnic nerve was also anæsthetized. The solutions used for this purpose were novocain, tutocain, and, later, percain.

"Spinal" anæsthesia requires no explanation, but it must be stated that the group under the heading of "Combined" consisted of cases in which local infiltration was used in combination with one of the inhalation anæsthetics.

Premedication.

A preliminary injection of atropine gr. 1/50 or gr. 1/100 was given to those patients about to have an inhalation anæsthetic, and a preliminary sedative, usually consisting of omnopon gr. 1/3 and scopolamine gr. 1/150, to those for whom a regional anæsthetic was prescribed.

Statistics.

It is fairly generally recognized that pulmonary complications occur chiefly in cases in which there has been surgical interference with the peritoneum, and for this reason abdominal operations at the Royal Victoria Hospital, Folkestone, were selected for this paper. These cases comprise the operations performed in the years 1929, 1930, and for the first six months of 1931, and their total number was 672.

The number of complications in these cases was 47, or 6.98 per cent of the total. These complications have been subdivided into two classes, and it is found that after upper abdominal operations the percentage of complications was 11.66, and after operations on the lower abdomen 5.97.

For the purposes of this paper the level of the umbilicus has been taken as the dividing line between the upper and the lower abdomen.

The incidence of complications in the upper and lower

abdomens, together with the anæsthetic used are shown in the following tables:

Anæsthesia	Total Number of cases	Number of complications	Percentage complications
Upper Abdomen			
General - - - -	74	7	9.45
Regional - - - -	33	5	15.15
Spinal - - - - -	5	—	—
Combined - - - -	8	2	25
Total - - -	120	14	11.66
Lower Abdomen.			
General - - - -	455	21	4.61
Regional - - - -	39	4	10.3
Spinal - - - - -	52	8	15.38
Combined - - - -	6	—	—
Total - - -	552	33	5.97

In an effort to demonstrate after which operations and under what conditions of anæsthesia these complications are most likely to occur, the series of "Upper" and "Lower" abdomens have been subdivided into the following tables:

The above statistics show clearly that, as a general rule, operations above the umbilicus have a higher percentage of complications than those below it. Of the upper abdominal operations those upon the stomach and duodenum are more prone to excite complications than those upon the gall-bladder and pancreas.

An interesting point about the lower abdominal procedures is that those carried out under spinal anæsthesia show the highest percentage throughout the entire series. Unfortunately the numbers in some of the sections are not large enough to allow a fair comparison to be drawn, especially as it must be taken into consideration that many of the less favourable cases were operated upon either under regional or spinal anæsthesia.

Anæsthetic	General			Regional			Spinal			Combined		
Operation	No.	Compli-cation	%	No.	Compli-cation	%	No.	Compli-cation	%	No.	Compli-cation	%
				(1) Upper Abdomen.								
Gastric and Duodenal Ulcer (not perforated) -	29	3	10.34	30	4	13.33	3	—	—	8	2	25
Gall-bladder -	23	2	8.69	2	1	50	2	—	—	—	—	—
Pancreas - -	4	—	—	—	—	—	—	—	—	—	—	—
Perforated Gastric and Duodenal Ulcer - - -	18	2	10.10	1	—	—	—	—	—	—	—	—
				(2) Lower Abdomen.								
Appendicitis -	214	6	2.8	7	1	14.28	18	2	11.11	2	—	—
Gynæcological -	123	4	3.25	—	—	—	12	2	16.66	2	—	—
Laparotomy (Obstruction Carcinoma large gut) - -	38	4	10.52	4	—	—	8	—	—	1	—	—
Bladder - -	18	1	5.55	12	1	8.44	2	1	50	—	—	—
Hernia - - -	62	6	9.67	18	2	11.11	10	3	30	1	—	—

Control Cases.

In addition to the above cases a further 250 consecutive cases of anæsthesia, where the peritoneum was not opened, were taken from the records of the Hospital. They included operations upon the breast, thyroid, limbs, genitalia, nose, and mouth, but no case of pulmonary complication could be found.

Operations for the removal of tonsils and adenoids have not been included, as it is considered that they probably have a certain incidence of pulmonary complications due to the inhalation of particles of tissue, and therefore do not come into the category of cases in which the cause of the complication is doubtful.

Age.

The complications recorded are found to occur at all ages, except in very young children. The youngest patient operated upon was aged six months, and the oldest was aged 88 years.

No complication was found in a child under the age of seven years.

The ages of patients were split up into groups of roughly 20 years, and the incidence of complications was found to be as follows:

Age	7–20	20–40	40–60	60–88
Number of Operations - -	111	223	244	94
Number of Complications -	4	15	18	10
Percentage of Complications -	3.60	6.72	7.34	10.63

Thus it will be seen that there is a definite increase of complications with advancing years, although spinal and regional anæsthetics are used with greater frequency in older patients.

Sex.

This series of cases comprises a total of 316 operations upon men, as against 350 upon women, and there were 34 complications (or 10.75 per cent of the total) amongst the

men, and 13 (or 3.65 per cent of the total) amongst the women.

Dr. Byrom, in a personal communication, gave me his analysis of 101 consecutive cases taken at the London Hospital. He found that 41 out of 64 (or 64 per cent) of the men showed bronchitis or some more gross involvement of the lungs, whereas after 37 operations upon women there was only one complication, and that a suspected embolism.

Seasons of the Year.

Post-operative pulmonary complications are much more common in the first three months of the year, as is shown by the following table:

Months	Jan. Feb. Mar.	April May June	July Aug. Sept.	Oct. Nov. Dec.
Number of Complications	20	14	11	2
Percentage of Total Complications - - -	42.55	29.78	23.40	4.25

The largely increased incidence in the first three months of the year is probably explained by the fact that the population is more prone to respiratory infections during this period. There seems no obvious reason why the incidence should be so low during the months of October, November, and December, although a decrease would be expected during the summer months.

Nature of the Complications.

As has already been stated, the complications found in this series of cases have been arbitrarily divided into two categories, namely those showing signs of bronchitis or broncho-pneumonia, and those showing evidence of gross consolidation of the lung.

These two categories are shown in more detail in the following tables:

(1) Upper Abdomen.

Operation	Gastric & Duodenal	Gall-bladder	Pancreas	Perforated Ulcers
Bronchitis and Broncho-pneumonia - - -	4	1	0	0
Consolidation of one base - - - - -	1	1	0	2
Consolidation of both bases - - - - -	4	1	0	0

Of these 14 patients, two (or 14.28 per cent) died. This makes an "anæsthetic" mortality of 1.66 per cent of the total of 120 operations.

The two patients who died were: (1) A woman, aged 72 years, who died of heart-failure following generalized bronchitis after an operation for cholecystectomy done under a general anæsthetic; (2) a man, aged 45 years, who died of an empyema following consolidation of the right base after an operation for perforated duodenal ulcer, also done under a general anæsthetic.

This makes a percentage of deaths of 2.70 for those cases done under general anæsthesia, whereas there was no mortality with regional anæsthesia.

(2) Lower Abdomen.

Operation	Appen-dicitis	Gynæco-logical	Lapar-otomy	Bladder	Hernia
Bronchitis and broncho-pneumonia - -	5	3	2	1	9
Consolidation of one base - - - - -	4	3	2	1	2
Consolidation of both bases - - - - -	0	0	0	1	0

Of these 33 patients, four (or 12.12 per cent) died. This makes an "anæsthetic" mortality of 0.72 per cent of the total of 552 operations.

The deaths in this category were as follows:

(1) A boy, aged 18 years, who was operated upon for acute

appendicitis, under general anæsthesia, and who developed consolidation of his left lower lobe. Post-mortem the condition was found to be tubercular pneumonia.

(2) A man, aged 76 years, died of acute bronchitis after prostatectomy under general anæsthesia. He was suffering from chronic bronchitis when admitted to hospital.

(3) A man, aged 44 years, died of an empyema following consolidation of both lower lobes of his right lung after resection of gut under general anæsthesia.

(4) A man, aged 85 years, died of consolidation of his right lower lobe following prostatectomy under a regional anæsthetic.

This makes a mortality of 0.65 per cent under general anæsthesia as against 2.56 under regional anæsthesia. The death following regional anæsthesia is perhaps hardly fair statistically, as it is possible that a man of his age might contract similar complications solely from being confined to his bed.

Characteristics of Complications.

Most observers agree that pulmonary complications occur within 72 hours of the operation, and it would indeed be unfair to class any rise of temperature or cough occurring after this period as directly due to the operation or to the anæsthetic. Foss and Kupp state that the day of origin varies from the second to the seventh according to the variety of the complication, but in the cases under consideration the onset was found to be largely in the first 24 hours, as is shown by the following table:

	Within 24 hrs.	Within 48 hrs.	Within 72 hrs.
Number of Cases -	39	7	1
Percentage of Total	82.97	14.89	2.11

(1) *Bronchitis and broncho-pneumonia.*

The typical onset is associated with cough and usually a rise of temperature. The temperature may range from 98.4 to 103, but it usually varies between 99 and 100 in the first 24 hours. In only one case was a temperature of 104 registered,

and that was in a boy, who was found at post-mortem examination to have contracted tuberculous pneumonia.

The cough is at first dry and unproductive, but this is followed later by the expectoration of varying quantities of very tenacious mucus, which sometimes becomes muco-purulent.

Examination shows rhonchi and crepitations scattered throughout the chest. If the case be one of uncomplicated bronchitis or broncho-pneumonia, the temperature gradually settles, and expectoration becomes less until the patient is normal again.

There were 25 cases of this type in the 47 complications recorded. Their duration varied between three and 14 days, with an average of 8.16 for the 25 cases.

Illustrations of the usual progress of this type of case is provided by the following charts and notes.

CASE I.

H. W., male, aged 22 years. Operation 28.3.31. Appendicectomy. Anæsthetic, A.C.E. mixture followed by open ether.

Subsequent Progress.

29.3.31.—Temperature 100. Respirations 28. Pulse 100. Troublesome cough with expectoration of tenacious mucus. Examination shows generalized bronchitis over entire chest. Symptoms and signs gradually abated until patient was normal on April 5th.

CASE II.

B.M., female, aged 18 years. Operation 12.2.31. Appendicectomy. Anæsthetic, spinal.

Subsequent Progress.

13.2.31.—Temperature 99.8. Respirations 24. Pulse 82. Slight cough with some sputum. Signs of generalized bronchitis in chest. Gradually settled until normal on February 9th.

COMMENTS ON THE ABOVE CASES.

This class of complication requires little explanation. The vast majority of cases show signs of a mild or moderately severe bronchitis. In a much smaller number of cases the severity of the symptoms, and the nature of the signs justify a diagnosis of broncho-pneumonia, but the difference between the signs and symptoms in a case of severe bronchitis and one of broncho-pneumonia is so small that these two types

of complication present a very difficult differential diagnosis, and are therefore grouped together here.

The primary symptom is a cough, at first unproductive, but later resulting in the expectoration of mucus or muco-purulent sputum. Pyrexia, together with a moderate acceleration of the pulse and respiration rates, may or may not be present. The temperature, pulse, and respirations gradually return to normal, the cough lessens, and the patient ceases to bring up sputum. This is the almost invariable course of post-operative bronchitis, and further sequelæ are rare.

(2) *Consolidation of part of one or both lungs.*

The remaining 22 cases, of the total 47 complications, showed two different sequences of physical signs, but in all of them collapse or consolidation of part of one or both lungs was diagnosed. Seven of these 22 demonstrated all the signs and symptoms of acute bronchitis, which were followed by signs of consolidation in a period varying between 24 and 48 hours after the onset of bronchitis. The remaining 15 showed no physical signs until consolidation was definitely established. In this paper these two types of consolidation have been classed together, as the ultimate course of events is similar in both.

The signs of consolidation consist of dullness to percussion, much diminished breath sounds (or less commonly tubular breathing), and coarse crepitations over the affected area.

In cases showing the larger amounts of consolidation there is deviation of the apex-beat towards the affected side.

Sputum is copious about 24 hours after the onset, and gradually diminishes until the patient is normal. It consists, usually, of tenacious muco-purulent material, and in only two cases was "rusty" sputum seen.

Pyrexia is, on the whole, not as marked in these cases of consolidation as in those which exhibit only bronchitis.

Respirations are increased in rate, but are not usually as rapid as in lobar pneumonia.

The characteristics described above are well illustrated in the following typical examples of the condition.

CASE I.

R.S., male, aged 67 years. Operation 19.5.31. Cholecystectomy. Anæsthetic, para-vertebral.

Subsequent Progress.

20.5.31.—Severe cough. No sputum. Temperature 99. Respirations 20. Pulse 88.

Examination shows dullness to percussion with diminished air-entry and a few scattered coarse crepitations at the base of the right lung. Temperature varied between 99 and 100 until 26.5.31. Physical signs remained unchanged until this date, but then gradually disappeared until the chest was normal 3.6.31.

CASE II.

H. P., male, aged 45 years. Operation 16.9.30. Obstruction of small gut due to bands; bands severed. Anæsthetic, regional, combined with nitrous oxide and oxygen.

Subsequent Progress.

17.9.30.—Irritating cough. No sputum. Temperature 100. Respirations 28. Pulse 120.

18.9.30.—Temperature 100. Respirations 32. Pulse 108. Patient bringing up copious sputum. Examination shows dullness at both bases of lungs.

Temperature remained between normal and 98.8 until 23.9.30, after which date temperature remained normal. Signs in the chest gradually disappeared until nothing abnormal could be found on 1.10.30.

CASE III.

R. C., male, aged 10 years. Operation 13.2.31. Appendicectomy. Anæsthetic, A.C.E. mixture, followed by open ether.

Subsequent Progress.

14.2.31.—Temperature 104.4, falling in the evening to 101.2. Respirations 36, falling to 24. Pulse 112. Very marked cough with scanty sputum.

Examination shows generalized bronchitis all over the chest together with dullness to percussion and diminished air-entry over left base.

16.2.31.—No bronchitis, but signs at the left base unchanged.

18.2.31.—Temperature normal and no signs remaining in chest.

CASE IV.

C. H., female, aged 71 years. Operation cholecystectomy 13.2.31. Anæsthetic, A.C.E. mixture, followed by open ether.

Subsequent Progress.

14.2.31.—Patient slightly cyanosed. Temperature 99.2. Respirations 32. Pulse 120. Severe cough with copious sputum. Examination shows generalized bronchitis all over the chest, together with dullness to percussion and diminished breath sounds over both bases.

Patient's temperature fluctuated between 98 and 99.6 and physical signs gradually diminished until the patient was normal on 7.3.31.

Comments on the above Cases.

In each of these cases the widespread distribution of the consolidation might have led an observer, unacquainted with the condition of pulmonary collapse, into the diagnosis of lobar pneumonia. The local signs, however, were more suggestive of diminished air-entry than of pneumonia consolidation. The disease started in seven out of the 22 cases as an acute bronchitis, and in the remaining 15 cases the first sign was that of collapse of a part of one or both lungs. Moreover the rise of temperature was often gradual, remittent, seldom exceeded 101 or 102, and subsided by lysis within a few days, while the pulse and respiration rates were only moderately increased. In no case was the onset heralded by rigors or pleuritic pain, and in only two instances was "rusty" sputum noted. Finally, there was clinical evidence of slight deviation of the heart towards the affected side.

For these reasons, and following the experimental evidence of Band and Hall, it may reasonably be presumed that collapse is caused by the secretion of tenacious mucus in the bronchi.

Discussion.

To these pulmonary conditions numerous writers have assigned various causes, and have produced different theories as to their origin, but there would appear to be one essential factor in their causation, namely the excretion in the bronchioles of a varying quantity of mucus of a certain viscosity. The cause of this mucus is by no means certain. The actual irritation produced by an anæsthetic vapour can play, at most, only a minor part, as is evidenced by the frequent occurrence of complications after regional and spinal anæsthesia. For the same reason aspiration of infected material from the mouth and pharynx cannot solely be blamed.

It is probable that the higher incidence in men is due to the fact that more upper abdominal operations are performed on men than on women, also to the fact that the average male hospital patient does not give up his work until obliged to do so, by which time his resistance is very poor. It may also be that men are more prone to chronic catarrhal bronchitis due to the habitual inhalation of tobacco smoke, the

consumption of alcohol, and daily exposure to cold and damp.

That the incidence should be highest in the first three months of the year is undoubtedly explained by the prevalence of catarrhal infections during these months.

It is almost certain that older people are more easily affected because in later life chest diseases are much more common.

After an abdominal operation, whatever the anæsthetic employed, the general resistance of the body is lowered. Ventilation of the bases of the lungs is hindered by the supine position, and movement of the diaphragm is lessened by the pain of an abdominal wound and the application of tight dressings. Still more importantly, all these factors inhibit coughing, by which means alone can any mucus secreted in the bronchioles be evacuated from the chest. Consequently the secretions accumulate, and a slight catarrh becomes an acute muco-purulent bronchitis.

Subsequent events are governed by the resistance of the patient, and the severity of the bronchitis. In some cases the condition subsides in a few days, but under more adverse conditions, the inflammation may extend peripherally, and cause blocking of the smaller bronchioles, thus giving rise to collapse of small areas of the lung, and causing a condition resembling broncho-pneumonia.

It would appear that collapse of larger areas is caused by the blocking of a bronchus by the secreted mucus. The air distal to this obstruction is then absorbed, thus giving rise to an area of collapse.

Finally, an important point brought out in this investigation would seem to be that, although patients operated upon under regional and spinal anæsthesia show almost as high an incidence of pulmonary complications as those done under a general anæsthetic, the operative mortality with this form of anæsthetic is very definitely lessened.

Prophylaxis and Treatment.

Various methods of prophylaxis and treatment have been advocated by the observers on the subject.

Jones and McClure claim a reduction of 50 per cent in

post-operative complications by the use of a transverse incision in upper abdominal operations, as they state that this incision causes less pain and therefore less limitation of respiratory movements.

Scott and Cutler recommend routine hyper-ventilation of the lungs with a mixture of carbon dioxide and oxygen at the end of all operations, and in addition they nurse the patient in a semi-Fowler position, give regular periods of deep breathing, and use dressings which do not hinder respiration.

Elliott and Dingley recommend the avoidance of tight bandages, and advise full inspiratory movements (particularly of the abdominal type) for all patients after operation, whilst Charlton Briscoe considers that the best method of prophylaxis is a minimum of repose in the supine position.

Sante advises rolling the patient from the affected to the unaffected side, whilst Foss and Kupp combine the above two methods, together with the curtailing of post-operative sedatives, and, if necessary, the removal of mucus with the bronchoscope.

Following Scott and Cutler's line of thought, Byrom treated 100 consecutive cases alternatively with hyper-ventilation with 20 per cent carbon dioxide in oxygen at the end of operation. He found that of those treated 70 per cent developed complications, whereas, in the untreated cases only 58 per cent were affected. He suggests that the reason for this is that the essential effect of hyper-ventilation is to draw any mucus secreted further into the lung by the enormous increase in respiratory excursion, and concludes that coughing, which involves forced *expiration* is the only effective means of removing excessive secretion.

From a study of the papers quoted it would seem that a combination of these methods must be used in order to diminish post-operative complications, and in the writer's own experience the following measures seem to be of most value:

(1) That as little pre- and post-operative sedative as possible be given, as all sedatives tend to depress the respiratory centre.

(2) That larger doses of atropine than are usually exhibited be prescribed in order to diminish the tendency

towards excessive secretion of bronchial mucus. The suggested dose is gr. 1/50 for adults, and proportionately less for children according to age.

(3) That no binder be applied to the patient's abdomen, but that all dressings should consist only of a roll of gauze secured by deep sutures.

(4) That all patients be made to exert strong expiratory movements at frequent intervals for at least the first 48 hours after operation. The exhibition of mixtures of carbon dioxide and oxygen would seem definitely to be contra-indicated, owing to the possibility of the mucus being dragged further into the lung by the strong inspiratory movements caused. Also patients, when conscious, are rendered extremely uncomfortable by the administration of these mixtures.

Conclusions.

(1) That post-operative complications occur no more frequently after general anæsthesia than after procedures under regional or spinal anæsthesia.

(2) That these conditions are common after abdominal operations but very rare after any procedure not involving the peritoneum, and that they are most common after operations on the upper abdomen, probably owing to interference with the diaphragm and limitation of respiratory movement.

(3) That the most usual conditions met with are either (1) an acute bronchitis or broncho-pneumonia of varying severity, which may clear up of its own accord, or proceed to (2) a condition of collapse of part of one or both lungs.

(4) That the cause of these conditions is the obstruction of bronchioles by tenacious mucus, and that treatment should be directed towards the expulsion of the mucus by coughing, rather than to hyper-ventilation by mixtures of carbon dioxide and oxygen.

(5) That these complications show an increased incidence in the winter months, but occur in all seasons.

(6) That older patients are more susceptible than the younger, and men more so than women.

(7) That treatment should be aimed at preventing, rather than curing, these conditions.

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NORMAL REGULATION OF RESPIRATION.

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(Read before the Section of Anæsthetics, Royal Society of Medicine).

Respiratory Centre.[1]

THE respiratory centre probably extends throughout the pons and the upper part of the medula oblongata. Trans-section of the midbrain in animals has no effect on breathing, but if the upper part of the pons is damaged the respiratory rhythm becomes markedly altered. Inspiration is now very deep and may be prolonged for two minutes or more; the inspiratory muscles are so violently contracted that it is difficult to expel the air manually from the chest. The inspiratory muscles then relax, at first gradually and finally suddenly and considerably, expiration thus taking place. The cycle then repeats itself. When the section is through the upper border of the medulla the type of breathing just described (which is called by Lumsden apneustic breathing) is replaced by a regular series of gasps. Trans-section at the level of the apex of the calamus scriptorius permanently ablishes all rhythmic respiration.

To explain these phenomena, Lumsden has postulated the presence of centres in the lower brain stem, each of which is released if the centre above is destroyed. In the upper medulla, below the striæ acousticæ, is a *gasping centre* which, when working alone, causes gasping respirations. Just above the level of the striæ acousticæ is the so-called apneustic centre, which is responsible for the prolonged inspirations. In the region of the upper pons is a centre which normally checks the activity of the apneustic centre and so produces normal respiration. The nerve cells having this effect he calls the pneumotaxic centre. There is no need,

however, to adopt this artificial subdivision of the central grey matter. Normally the "centre" acts as a co-ordinated unit; if parts of it are cut off, the portion left can no longer control breathing normally, and so the abnormal types of respiration are produced. Cases have been reported in infants in whom following birth injuries apneustic breathing has been observed; post-mortem hæmorrhages in the pons have been demonstrated.[2] When an animal is dying from asphyxia, overdose of anæsthetic, or interference with the medullary blood-supply, it may be noted that as the breathing fails it sometimes passes through the stages of apneuses and gasps; if the animal is revived breathing recovers in the opposite order.

Rhythmic activity of the respiratory centre.[3]

The respiratory centre is connected with, and controls the activity of, the lower motor neurones which supply the muscles of respiration. There is little doubt that the respiratory centre possesses an inherent rhythmicity, analogous to that of the auricular node of the heart. Under experimental conditions it still goes on discharging in a rhythmic manner after it has been isolated as far as possible from afferent impulses from the lungs, the circulatory system and the higher centres and after the respiratory muscles have been paralysed by means of curari (Adrian).

Direct recording of the electrical changes in the respiratory muscles shows that in cats and rabbits under chloralose anæsthesia the expiratory muscles may be regularly in action during the expiratory phase of the cycle; in the decerebrate preparation and in animals under dial and urethane they are occasionally in action, but never in deep chloroform anæsthesia. The expiratory muscles, however, always contract when the depth of respiration is increased.

The depth of breathing is mechanically regulated in a number of ways. It is well known that if skeletal muscle is stimulated at low rates it goes into partial tetanus and develops a low tension; if stimulated at sufficiently high rates it becomes fully tetanized and develops its maximal tension; further, the tension of a muscle will vary with the number of its fibres that are in action simultaneously. Appropriate

electrical studies[4] show that during quiet inspiration the diaphragm, for example, is being stimulated through its motor nerve at low rates (e.g. 25 per second); the tremulous state that might be anticipated from such incompletely maintained contractions is obviated by the various fibres of the muscle not all being in the same phase of activity simultaneously. In deep breathing a larger number of fibres come into action. They are stimulated more synchronously and rapidly (up to 60 or 100 per second) to give a full tetanus and the duration of the contraction may also be prolonged. If the respiratory centre is damaged or poisoned it is found that the nervous impulses reaching the respiratory muscles become more infrequent and of shorter duration; inspiration thus becomes feebler and brief and finally may cease completely.

Regulation of the breathing.[5]

A brief consideration of the purposes served by breathing forms the most satisfactory introduction to an account of its regulation.

(1) The self-evident reason for breathing is to obtain supplies of oxygen and get rid of CO_2 formed in the body. Our oxygen requirements and the amount of CO_2 liberated are proportional to the degree of activity of the body. The first law of breathing is therefore (all other things being equal), that the pulmonary ventilation *is proportional to the metabolic rate.* It can be shown that for every calorie of heat liberated in the body about 200 c.c. of oxygen must be used. Every 100 c.c. of inspired air provides about 5 c.c. of oxygen to the blood; it follows that a minute oxygen consumption of, say, 200 c.c. demands a pulmonary ventilation of 4 litres. In a man of average size and weight, the heat output under basal conditions (*i.e.* at complete rest 12 to 18 hours after a meal) is about 1.2 calories per minute, necessitating a ventilation of 5 litres. The above considerations show how the resting ventilation can be calculated in any individual. Any condition which alters the rate of metabolism, *e.g.* thyroid disease, exposure to cold, changes in body temperature, the taking of food, decompensated heart disease, etc., will all correspondingly modify the resting ventilation. In muscular exercise the oxygen consumption (and metabolic rate) may

increase up to 10 or 15 fold, or even more, necessitating a ventilation of 50 up to 100 litres per minute.

It will be shown later that the link between metabolism and pulmonary ventilation is probably provided by alterations in the CO_2 tension in the blood to which the breathing is exquisitely sensitive.

(2) The breathing responds in an extremely delicate manner to the slightest change in the H-ion concentration of the blood in such a way as will keep the reaction at its normal level. The second great principle to remember is that the pulmonary ventilation will vary with the *reaction of the blood*. This matter will be considered in greater detail later.

(3) The breathing is sometimes adjusted to *maintain the normal temperateure* of the body. When the body is exposed to warm and very moist external surroundings, regulation of body temperature becomes very difficult as heat loss by evaporation and radiation from the skin are greatly interfered with. The pulmonary ventilation under these conditions is greatly increased in order to eliminate more water vapour in the expired air and thus get rid of heat from the body. The alveolar and arterial CO_2 tension fall, but the alkalæmia resulting is compensated for in the usual way by the excretion of an alkaline urine.

(4) Changes in the *level of the arterial blood-pressure* modify breathing reflexly: a rise of pressure depresses breathing and a fall stimulates it.[6] This factor probably only comes into operation in the intact resting individual when the blood-pressure is altered rapidly and to a considerable extent.

(5) Under certain conditions breathing is adapted to *maintain the appropriate oxygen tension in the blood*. We shall see that breathing only responds to oxygen lack when it is severe. At sea-level when air of normal composition is inhaled oxygen lack can play little or no part in controlling breathing. At high altitudes, or in oxygen-poor atmospheres it becomes the dominating factor and stimulates breathing, although there is no change in metabolic rate, and although the effect of the hyperpnœa is to produce an alkalæmia. The goal of the respiration under these circum-

stances is, of course, to improve the oxygenation of the blood.

(6) The *rhythm* of the breathing is mainly controlled by the pulmonary afferents in the vagi.[7] The *sino-aortic* nerves which arise in the carotid sinus (a dilatation at the bifurcation of the common carotid artery) and the aortic arch play an important part in regulating the ventilation owing to the fact that their sensory nerve endings in the blood vessels are affected by changes in the pressure and chemical composition of the blood.

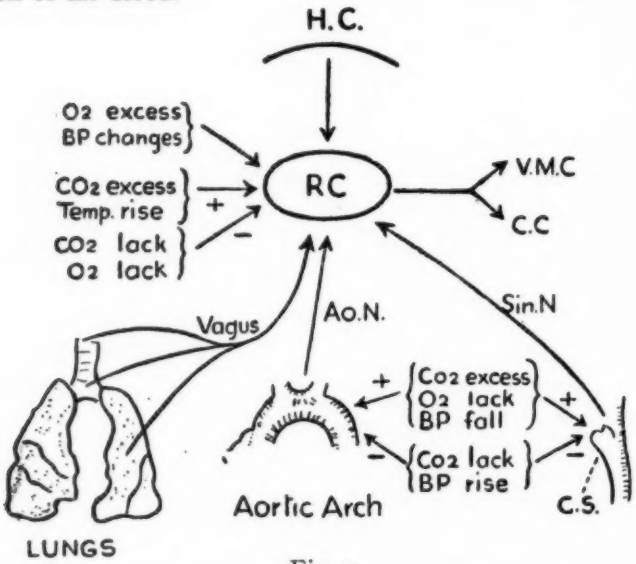

Fig. 1

R.C. = respiratory centre; H.C. = higher centre; C.C. = cardiac centre; V.M.C. = vasomotor centre; C.S. – carotid sinus region (including carotid body); Sin. N. = sinus nerve; Ao. N. = aortic nerve; + = stimulates breathing; – = depresses breathing.

(7) Lastly it should be remembered that the respiratory mechanism is definitely depressed in *sleep* and the breathing becomes inadequate for the needs of the body. We must now proceed to a more detailed discussion of some of the factors just referred to. Fig. 1 summarizes most of the information to be considered.

Carbon dioxide and breathing.

If air containing excess CO_2 is breathed, the ventilation is markedly increased, first by increasing the depth and later by also increasing the rate of breathing. There are considerable individual variations in the response. When the CO^2 percentage in the inspired air exceeds that found in alveolar air (5.6 per cent) adequate compensation becomes impossible and CO_2 is retained in the blood. Headache, diminished sensibility, weakness and mental confusion develop and later loss of consciousness may occur. Finally respiration is depressed and the circulation may fail chiefly because of poisoning of the heart.

If the carbon dioxide tension of the blood is artificially lowered by over-ventilation, breathing is depressed and may stop. Following the apnœa, periodic breathing may develop. The effects of over-ventilation also vary considerably, and in a proportion of subjects it appears to be impossible to arrest the breathing no matter how prolonged the period of hyperpnœa may be. If pure oxygen instead of air is inhaled during the period of forced breathing the duration of the apnœa is greatly prolonged, and in one recorded case lasted for eight minutes. If the over-ventilation is carried out with air containing more than 5 per cent CO_2 apnœa cannot be induced as the blood CO_2 is not lowered below the threshold level.

The other effects of over-ventilation in man are worth mentioning. There is leucocytosis, hyperglycæmia, diuresis (possibly due to increased blood-flow through the kidney resulting from splanchnic vaso-dilatation), increased excretion of phosphate, and the usual urinary changes to compensate for an alkalæmia, *i.e.* a more alkaline urine and lessened excretion of ammonium salts. Acetone bodies appear in the urine; this may mean that aceto-acetic and oxybutyric acid resulting from fat breakdown are passed into the blood to help preserve its reaction. The blood-pressure is little altered in spite of depression of the vasometer centre, possibly because of the intense constriction of the skin vessels which is usually noted; the skin is cold and white.

Mode of action of CO_2.[8]

Recent research has shown this to be of a complex char-

acter. CO_2 acts mainly directly on the respiratory centre, but it also acts partly reflexly by stimulating sensory nerve endings in the carotid sinus region and the aortic arch, thus sending excitatory impulses to the centre. After section of the sinus nerves CO_2 may produce a smaller increase in the ventilation than in the intact animal.

H-ion concentration and breathing.

Changes in the H-ion concentration of the blood due to causes other than increased CO_2 formation of the tissues or to excess CO_2 in the inspired air readily affect respiration, in order (as previously indicated) to preserve the appropriate blood reaction. Thus if the H-ion concentration is increased (acidœmia), the breathing is stimulated, and extensive amounts of CO_2 are eliminated from the lungs and blood; the amount of the carbonic acid in the blood is thus lowered and the H-ion concentration is consequently reduced to its proper level. Conversely when the blood reaction becomes excessively alkaline (alkalæmia), the breathing is depressed, CO_2 is retained in the blood and the consequent increase in H_2CO_3 helps to restore the normal reaction.

Common causes of acidœmia are (1) starvation, diabetes, or unbalanced carbohydrate to fat ratios in the diet leading to accumulation of acetone bodies; (2) the injection of ammonium chloride which liberates HCL in the body; (3) methyl-alcohol poisoning (owing to the formation of formic acid); (4) certain types of nephritis from retention of non-volatile acids. Alkalæmia may occur clinically, (i) from injection of excessive amounts of $NaHCO_3$; (ii) in plyoric or high intestinal obstruction and some cases of diarrhœa and vomiting. In the last group an increase in the amount of plasma bicarbonate is the cause of the alkalæmia, and this may be an attempt to maintain the osmotic pressure of the plasma and to compensate for the excessive loss of NaCL which is taking place in the vomit or fæces. In some cases of diarrhœa and vomiting, however, an acidœmia may be present; this is due to some extent to water loss causing anhydrœmia and defective renal circulation with consequent imperfect elimination of acid in the urine; in addition the impaired tissue circulation may lead to the formation of acid

non-volatile products of incomplete combustion of carbohydrate and fat. Changes in H-ion concentration appear to act in the same way as CO_2, *i.e.* mainly centrally and partly reflexly *via* the sino-aortic nerves.[7]

Oxygen lack and breathing.

It is well to emphasize two preliminary points. Firstly, the inhalation of pure oxygen has no effect whatsoever on respiration. Secondly, cyanosis depends solely on the presence of excessive amounts of reduced hæmoglobin in the capillary blood and so is an index of the degree of oxygen want. It is entirely unrelated to the amount of carbon dioxide in the blood.

The effects of oxygen lack are complex and depend mainly on the degree of acuteness and severity of the deprivation. (1) If an inert gas like nitrogen or nitrous oxide is breathed, the CO_2 is eliminated quite normally from the alveoli, but the oxygen which is present there is washed out as well. A certain degree of initial hyperpnœa occurs as a rule (though not invariably) but within 45 seconds' loss of consciousness develops suddenly, and practically without any warning, from oxygen lack to brain. There are no reserve stores of oxygen in the tissues (unlike CO_2); the only oxygen present there being the minute amounts which are present in solution. Soon after, breathing decreases and ceases from failure of the respiratory centre. (2) If the oxygen lack is less severe, the effects produced depend on how rapidly it is induced.

If the subject breathes in and out of a large bag through a soda lime chamber, the CO_2 evolved is removed by the soda lime and does not, therefore, accumulate in the bag. The oxygen content gradually diminishes. The breathing is unaffected till the oxygen in the bag is reduced by about one-third, *i.e.* from 21 to 14 per cent. In some sensitive subjects considerable increase in the breathing may now occur; but often the increase is too slight to be appreciable subjectively, though it can be shown to be taking place. It contrasts very strikingly with the intense hyperpnœa which results from even a small rise of CO_2 in the inspired air. Breathing is stimulated by oxygen lack, but to nothing like the extent to

which it reacts to CO_2 excess. The effect of the increased breathing is again to raise slightly the oxygen content of the alveoli, and to wash out excessive amounts of CO_2. As the blood becomes better oxygenated and its CO_2 content steadily falls, the breathing dies down again and never gets a chance to be maintained at a permanently high level. There is a tendency, too, for the breathing to wax and wane, *i.e.* be "periodic" in character, The effects may be summarized thus:

Oxygen-lack stimulates breathing, increases pulmonary ventilation, lowers alveolar CO_2, lowers arterial CO_2 alkalæmia, depresses breathing.

It is difficult to establish adequate compensation as the stimulus of oxygen lack to breathing tends constantly to be counteracted by the alkalæmia. Cyanosis develops when the oxygen content of the inspired air falls to 10 per cent, and this is accompanied by marked mental incapacity. Consciousness is lost a little later, from oxygen deprivation of the higher centres, without any air struggle.

(3) If the oxygen-lack is of very gradual onset and ample time is available for all the compensatory activities of the body to be brought into play the condition can be dealt with more effectively. This is well seen in gradual ascents to high altitudes. The essential point is that the kidney copes with the alkalæmia by excreting more alkali and making less ammonia. The blood reaction is in this way kept fairly normal and the ventilation is thus permitted to develop to, and remain at, the requisite high level. As a rule the increase in breathing resulting from oxygen-lack is chiefly in rate and to a less extent in depth.

Mode of action of oxygen-lack.[9]

As explained above, moderate degrees of oxygen-lack stimulate breathing in the intact animal. But if the sinus nerves and vagi are severed, inhalation of the same mixture as a rule rapidly develops paralysis of respiration. It can be concluded from this observation that oxygen-lack directly depresses the isolated respiratory centre; but it acts on the sensory nerve endings in the carotid sinus and the aortic arch setting up excitatory impulses which reflexly stimulate

breathing. As a rule in the intact animal the reflex stimulation prevails and increased ventilation results. It has already been pointed out how this hyperpnœa by washing out CO_2 sets up further complications. It is frequently stated that oxygen-lack sensitizes the respiratory centre to the action of CO_2; but this is incorrect. The "isolated" respiratory centre (sinus nerves and vagi cut) responds more vigorously to carbon dioxide excess alone than to carbon dioxide excess combined with oxygen-lack.

Blood-pressure, cerebral circulation and breathing.[6]

It has already been stated that a rise of blood-pressure in the intact resting animal reflexly depresses respiration, while a fall of blood-pressure reflexly stimulates breathing. The sensory zones which react to the blood-pressure changes are in the aortic arch and the carotid sinus. After section of the aortic and sinus nerves, blood-pressure alterations no longer affect breathing; this shows that changes in blood-pressure (so long as they do not lead to severe cerebral anæmia have no direct effect on the respiratory centre. It is worth stressing that the respiratory centres, more than the other bulbar centres, rapidly lose their excitability if their oxygen supply is cut off, or if their blood-supply is interfered with, as by raised intracranial pressure or by cerebral anæmia. If the blood-pressure is raised and the cerebral blood-flow is improved rhythmic respiration may be restored.

Role of the vagi in respiration.[3]

The vagal afferents which come from the laryngeal mucous membrane are concerned with the cough reflex and guard the respiratory passages against the entrance of foreign bodies. The afferent fibres which come from the substance of the lung undoubtedly regulate the rhythm of breathing.

As is well known, division of both vagi produces slowing and deepening of breathing. Paralysis of the laryngeal muscles is produced at the same time and causes obstruction of the air-way which itself slows down breathing, but the slowing is obtained equally well when the vagi are divided in the tracheotomized animal so that it is probably due essentially to the cutting off of afferent impulses from the lungs.

A good deal of light has been thrown on this subject by the studies of Adrian on the action currents (which are set up by nervous impulses) in single fibres of the vagus. It is found that a stream of impulses passes up during inspiration; the frequency of the impulses varies directly with the degree of distension of the lungs, and it dies down again during expiration. The impulses are probably set up by nerve-endings in the lung which are stimulated by stretch and which behave very similarly to the stretch receptors in muscle. If the lungs are artificially distended an impulse stream is set up (similar to that observed during normal inspiration) and it continues practically unaltered for as long as distension is kept up. *Forcible collapse* of the lungs induced by sucking out the contained air sets up another impulse stream which may arise from a distinct set of nerve endings; probably, under normal conditions, they only come into operation very exceptionally.

The physiological effects of these vagal afferent impulses are shown by Head's experiments: if the lungs are forcibly distended a prolonged expiratory effort is reflexly produced; if the lungs are collapsed a strong inspiratory effort is made. These results are not obtained after section of the vagi, proving that these nerves form the afferent limb of the reflex arc employed.

The conclusions which can be drawn from the above observations are as follows: The vagi signal the degree of expansion of the lungs; normally, when inspiration has proceeded to a certain degree, afferent impulses are set in the vagi which check inspiration, and consequently expiration takes place. It has been pointed out that the respiratory centre possesses inherent rhythmicity. When it is cut off from vagal afferents it discharges for a long time (giving a deep inspiration) and then passes into a long rest period during which it can recover to its original state. The presence of vagal afferents cuts short inspiration so that it becomes more shallow; as the period of activity is short, the time necessary for recovery is similarly abbreviated, and consequently the next inspiration follows more rapidly, so leading to an increased respiratory rate. As explained, afferent impulse streams are only set up very exceptionally during expiration.

Role of afferents from cardiovascular area.

As has been pointed out, the endings of the sinus and aortic nerves in the carotid sinus and aortic arch respectively are sensitive to changes in blood-pressure, the CO_2 tension, the H-ion concentration and the oxygen content of the blood. A fall of blood-pressure and a rise of CO_2 tension or of H-ion concentration, and oxygen-lack reflexly (via these afferent nerves) stimulate the respiratory centre.

Conversely a rise of blood-pressure and a fall of CO_2 tension or of H-ion concentration reflexly depress respiration.

Influence of respiratory centre on other bulbar centres.

Sinus arrhythmia (the variation in cardiac rate which occurs normally with respiration) has been shown to be due to an irradiation from the respiratory to the cardiac centre.[10] During inspiration the activity of the vagus centre is diminished and the heart quickens, while during expiration the discharge of the vagus centre is increased and the heart is slowed. It has further been shown[11, 14] that the respiratory centre also irradiates directly to the vasomotor centre; during inspiration the discharge of the latter centre is increased causing greater arteriolar constricton and a tendency for the blood-pressure to rise; the reverse process takes place during expiration.

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CASUAL COMMENTS.

We observe from a number of papers contributed to the *Indian Medical Gazette* of December last that anæsthesia is at long last taking its proper place in practice on that continent.

The advent of skilled administration on a wide scale in India has been long delayed, and it is only within the last 10 years that real steps have been taken to make use of the knowledge and practice which have become commonplaces in most civilised countries. Till that time the practice of anæsthetics in India meant little more than administration of chloroform, often by a person qualified neither legally nor by training, nor indeed by any quality but a certain amount of ill-founded self-confidence. The reasons why India lagged behind are easy to see. They were partly economical. The cost of apparatus for proper giving of nitrous oxide and of ether is much more than that of the simple contrivances which are all that are needed for chloroform. The latter is convenient, too, because of the comparatively small amounts of it that are needed owing to its greater potency, which is, of course, at the same time the best reason for avoiding it as a routine agent. Again ether was held by many to be ruled out by climatic conditions. That this was a justifiable reason for avoiding its use has been disproved by many who disbelieved that the temperature of the country prevented the use of ether in India if care was taken with its storage. Another reason which delayed the development of skilled anæsthesia was probably the comparative laxity of arrangements for inquiry into the cause of death when persons succumbed at or soon after operation.

Whatever the reasons for the delay, it is good to know that now, at least in the great hospitals, the most recent advances in the practice of anæsthesia are utilised. Basal narcotics and spinal analgesia in particular are modern methods likely to be of the greatest service in conditions of Indian surgical practice, and are evidently becoming firmly established there. It does not seem likely that the use of nitrous oxide for major surgery can become common. The necessary apparatus is very expensive, somewhat cumbrous and probably more difficult to keep in order than in cooler climates. Also a class of men with the necessary special skill must be brought into being before the method can be used over a wide field.

A leading article in a recent number of the *New England Journal of Medicine* is headed "Obstetrical Analgesia: A Warning." This comprehensive and somewhat alarming title is hardly borne out by the contents of the article, which are solely directed to the use of barbiturate preparations at confinements in private houses. The writer points out, perfectly, that an inconvenient and possibly a dangerous condition of

excitement follows the use of these preparations in a large number of instances. Therefore they are only to be used with safety where, as in hospital, there is effective control of the patient throughout. The ideal analgesic for general use in midwifery is still being sought. It is not likely to be found among the barbiturates. Probably chloroform capsules even, are, taken all round, less dangerous than barbiturate hypnotics in the circumstances. The efforts that are being made to render nitrous oxide and oxygen practicably possible may, it is hoped, end in bringing the least toxic of all anæsthetic agents into general use in midwifery.

Two new general anæsthetics are attracting some attention, although as yet it has not been possible to submit either of them to extensive trial. They are divinyl ether and cyclopropane. The former appears to be both difficult to manufacture and so volatile that its preservation is also difficult. The latter suffers from the practical obstacle that it is at present so expensive that wide use is almost prohibited. If this difficulty could be overcome there might well be a great field for cyclopropane. It appears to offer many advantages, speed and comfort of induction, quiet breathing, rapid recovery, complete relaxation. Moreover, not so much premedication is needed for perfect anæsthesia as is necessary when "gas and oxygen" is the chief inhaled anæsthetic.

ASSOCIATION OF ANÆSTHETISTS OF GREAT BRITAIN AND IRELAND

In the list of the newly elected Council, given in our last number, the name of E. Falkner Hill, M.D. (Manchester) was by mistake omitted.

The next general meeting will take place too late for report in this number of the Journal. The Council in the meantime have had several meetings in London and, among other matters, has had under discussion a letter from the Board of Education, who sought its advice on an important question concerning the administration of anæsthetics for tonsil and adenoid operations at children's clinics.

The payment of anæsthetists attached to surgical units, and coroners' inquests on deaths associated with anæsthesia, are other matters with which the Council has been occupied. We understand that the institution of a diploma in anæsthetics is also engaging the earnest attention of the Council.

SECTION OF ANÆSTHETICS.

(Royal Society of Medicine)

At a meeting on February 2nd, Dr. H. P. Fairlie, the President, in the Chair, a discussion was held on "Modern Views on Respiration." We give a full résumé of the opening paper elsewhere. Dr. Alan Moncrieff contributed a paper on respiratory failure. He said that the close relation between the circulatory and respiratory systems make the problem complicated. In the new-born the factors were simpler than in later life. The subject here was of interest to anæsthetists because of the need for intubation and insufflation of gas mixtures. Obstruction, delayed expansion of lungs, narcosis, circulatory failure, intracranial damage and an abnormal centre were the causes discussed.

The use and value of carbon dioxide were described, and also the dangers of hyperventilation. Respiratory failure in general was due to central or to peripheral causes. The latter included mechanical causes, interference with ventilation in the main air-passages and with gaseous exchange between blood and alveolæ, circulatory disturbances in the lungs, and altered composition of the inspired air. For treatment chief reliance must be placed on carbon dioxide and oxygen and on artificial respiration. There was a lack of effective drugs, and those available had their limitations.

The meeting on March 2nd was given up to discussion of clinical cases, and was not for publication.

ABSTRACTS.

Relief of pain in labour with nembutal. F. G. McGuinness. *Canad. Med. Assoc. Journ.*, February, 1934, p. 162.

The author offers a report on 140 full-time confinements in which nembutal was used by the mouth to produce amnesia. In every patient the fœtus was known to be living at the onset of treatment. The patients included instances of mild toxæmia of pregnancy, mitral stenosis (2), pulmonary tuberculosis and eclampsia. Nembutal is stated to increase the effect of morphine even more than do scopolamine and magnesium sulphate, and for this reason it was not employed after a few trials by the author. Chloral hydrate was also given up, and replaced by a larger dose of nembutal. Fifteen grains of this drug were used in twenty-four hours. Six grains were given as an initial dose, a second dose of two grains not less than three hours later, and one and a half grains every succeeding two hours or more if amnesia was not complete, till delivery. The capsules were given on an empty stomach, with warm water. The room was darkened and all noise avoided. The patient was generally sleeping soundly between pains half an hour after the first dose. She would groan or be restless during a constriction and fall asleep directly it was over. The pulse-rate varied little and blood-pressure fell at most 24 mm. Hg. Nausea and vomiting were not increased either before or during delivery. There was no apparent effect on pregnancy or power of uterine contraction, nor on the condition of the infant. Respiratory obstruction or infection, asthma, low blood-pressure and serious damage to cerebro-vascular system or kidney are the contra-indications admitted by the author, who believes that nembutal provides a simple and effective means of controlling the pains of labour.

Researches into the alteration of the cerebro-spinal fluid after spinal anæsthesia. N. Backer-Grondahl. *Acta Chir. Scan.*, lxviii, p. 485.

In order to see any changes in the fluid after spinal anæsthetic injection the author made lumbar punctures in numerous patients at intervals of 24, 48, and 72 hours after they had received a spinal anæsthetic. Without going into detail his conclusions may be roughly stated thus: After almost every spinal injection there is an increase in the cellular content of the spinal fluid. This increase appears soon after the injection and it also disappears quickly. When, for example, a patient in whom affection of the sixth nerve appeared eight days after injection was punctured, and the fluid examined, it was found normal with no increase of cells. Increase of cells, says the author, is the

most obvious and characteristic trait of the reaction of the spinal meninges to injection of anæsthetics, whatever these may be. There did not appear to be any definite association between the cellular increase and headache after injection. Some patients with great increase had no headache, and others with severe headache had but slight cellular increase.

Ether and chloroform narcosis as a treatment for cancer. R. W. BONNER. *Clin. Med. and Surg.*, January, 1934, p. 11.

The author has been struck by the large number of instances in which a patient has improved after the removal of an abdominal metastatic mass or after a purely observational laparotomy. This has led him to suspect the action of some other factor than surgery. He gives reasons for believing this factor to be the inhaled ether or chloroform. He shows how the action of these drugs on tissues and on blood resembles the action of radium and of X-rays. Cancer should be attacked, he maintains, by repeated inhalations of ether or chloroform, sufficient to produce complete narcosis and repeated often enough to bring about destruction of the growth or its arrest. Working on these lines he claims that he has had gratifying results. The weak point of the article is the complete absence of detailed case reports to maintain the theory advanced.

Local anæsthesia for post-operative pain after abdominal operations. W. CAPELLE and E. FULE. *Deutsch. Zeitschr. f. Chir., November* 8, 1933.

After animal experiments the authors tried their method on four patients. The results were excellent. The patients were free from pain, breathed freely and coughed without restraint. The bowels moved without medicine and the incisions healed normally. The treatment is carried out by the insertion of three hollow needles, parallel to the abdominal incision, subperitoneally, intramuscularly and subcutaneously. Five times daily an injection of 10 c.c. of weak novocain in normal saline was given. The treatment lasted for five days.

The human heart in anæsthesia. I. G. W. HILL. *Edin. Med. Journ.*, Vol. xxix, No. 9, and *Lancet*, May 28, 1932.

The research described in the above articles gives valuable experimental support to the common clinical view that the early stages of induction with chloroform are the times of peculiar danger. It is with chloroform alone among anæsthetics that death occurs suddenly due to the anæsthetic and before full narcosis has been reached. The experiments show that in half of the subjects to whom chloroform was given from the start the heart is affected in a particular way. This is by the occurrence of extrasystoles. These in themselves are harmless and produce no effect on blood-pressure, nor is the pulse notably irregular.

The importance of the condition lies in the fact that it leads easily to the far more serious state of ventricular fibrillation. The occurrence of extrasystoles in early chloroform narcosis in the human, as shown in text studies of electrocardiography, is exactly similar to that demonstrated by Levy in cats, and he showed that in them the state led in occasional instances to the onset of ventricular fibrillation and that this was sometimes fatal. The circumstances associated with the extrasystoles in man, excitement, fear, struggling, etc., are exactly comparable with those in the cat, and there is every reason to believe that the consequent occasional fibrillation may occur in man just as it does in the cat.

Investigations of post-operative acidosis and ketonuria. F. ROSCHER. *Acta Chir. Scandinav.*, Vol. lxxiv, Supp. xxix.

This is a comprehensive account of the conditions dealt with. Its object was not to find out which are the acids causing acidosis, but to determine their aggregate effect on the acid-base balance of the organism. The author decides that minor importance is to be attached to post-operative acidosis and ketosis in adults, but not so in children. He believes that no treatment is necessary in most instances, but that the organism ought to be assisted in its effort to compensate post-operative acidosis. The assistance should consist of a liberal supply of liquid during the whole post-operative period—about two litres of liquid daily. Till the salt content of the food is sufficient this liquid must include about one litre of Ringer's solution or physiological salt water daily.

Nembutal and scopolamine analgesia in labour. L. AURETT. *Amer. Journ. Obstet. and Gynecol.*, January, 1934, p. 109.

The author has used the combination in 169 instances. He believes it to be safe and effective in obtaining obstetric analgesia. In 110 patients there was complete amnesia; in 42 there was some recollection of a few incidents, but little recollection of pain. In eight multiparæ there was complete failure. These patients were well advanced in labour on admission to the hospital and were delivered in from one to one and a half hours after the medication. The dosage was six grains of nembutal at one time, by the mouth, and scopolamine gr. 1/100 hypodermically, when uterine contractions were taking place, at five-minute intervals.

Anæsthesia with evipan. L. DI NATALE. *Annali Italiani di Chirurgia*, November 30th, 1933.

Evipan is to be considered as an ideal anæsthetic in short operations and for the treatment of casualties. It can also be used as a basal anæsthetic in major operations, and in these cases the supplementary anæsthetic (ether or chloroform) should not be given before fifteen

minutes have elapsed. Complete anæsthesia for long and difficult operations can be obtained by the administration of small doses of evipan repeated at intervals. The effect of the drug is rapid and complete anæsthesia is certain. Evipan is perfectly tolerated and, if used carefully and with proper technique, is neither dangerous nor toxic. The return to consciousness is gradual and almost peaceful. The patient does not have any recollection of the operation.

Obituary.

Llewelyn Powell, M.A., M.B.

THE sudden death, on January 27th, of Dr. Llewellyn Powell removed from the anæsthetists of London a man who was greatly beloved and respected and will be sorely missed. Powell was educated medically at Cambridge and St. George's Hospital, to which institution he was at the time of his death consulting anæsthetist. He had been anæsthetist also to the National Hospital, Queens Square, the Samaritan, and Queen Charlotte's Hospitals. Through his connexion with these hospitals and owing to his professional skill and engaging personality, Powell enjoyed for many years a large private practice as an anæsthetist in London. He played, too, a prominent part in the affairs of the anæsthetic section of the Royal Society of Medicine, of which he had been in his turn secretary and president. Nevertheless it is true, as was said in an obituary notice in *The Times* that he will be remembered even more for his personal than for his professional qualities. Powell had indeed exceptional social qualities. He was witty, cheerful, shrewd and generous. He had exceptional talent, too, as an actor and comic singer, and these talents were freely used for the entertainment of his friends and for the benefit of charities whenever they were asked for. Powell did not make many contributions to the literature of his speciality, but the large number of students who passed through his hands benefited by the instruction of a man of sound judgment, common sense and acute sense of the duties and obligations of the anæsthetist. We cannot do better than end this short notice with a quotation from the writer already alluded to, who described Powell as "a rare personality, sure and worthy of love and remembrance."

J. B.